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# National Center For Agricultural Utilization Research

## Peoria, Illinois

United States
Department of
Agriculture

National Agricultural Library

Cover photo:
*DNA screening of gene required for biosynthesis of mycotoxins.*

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# Contents

# The Agricultural Research Service

The Agricultural Research Service (ARS), the in-house research arm of U.S. Department of Agriculture, develops new knowledge and technology to solve technical and agricultural problems to meet the nutritional needs of the American consumer, to sustain a viable food and agricultural economy, and to maintain a quality environment and natural resource base.

*Greenhouse evaluation of starch encapsulated biological pesticides.*


National Center for
Agricultural Utilization
Research
MIDWEST AREA
AGRICULTURAL RESEARCH SERVICE
U.S. Department of Agriculture
USDA

# NCAUR Mission: Turning the Green to Gold

The National Center for Agricultural Utilization Research (NCAUR) is a major ARS research facility. Work at NCAUR focuses on commercialization of products and uses for agricultural commodities and encompasses three areas: finding new market opportunities for commodities, securing environmental quality and compatibility, and ensuring food safety.

Expansion and diversification serves to strengthen international competitiveness, enhance exports, and reduce imports. NCAUR's contributions in attaining this goal include:

- developing environmentally safe, value-added industrial and food products and uses from agricultural commodities and their products

- exploiting natural biosynthetic systems and associated genes coding for useful products

- in conjunction with Federal regulatory and action agencies, developing technology that can enhance competitiveness of U.S. agricultural products

As the designated lead USDA Technology Transfer Facility, NCAUR eases and accelerates commercialization of promising products and technology—working to bring them out of the lab and into the marketplace.

*The National Center for Agricultural Utilization Research, Peoria, Illinois.*


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# What NCAUR Means to America

It is impossible to deny the importance of research performed at NCAUR, beginning with the lifesaving antibiotic penicillin that became available in large quantities to the world thanks to NCAUR work. With this breakthrough and so many other high-impact developments, it is hard to believe that when NCAUR (formerly the Northern Regional Research Laboratory/ Center) was established by an Act of Congress in 1938, the team of scientists who gravitated to Peoria was comparatively obscure.

The lab's objective at the time was to develop new products made from agricultural commodities and processes that would result in greater consumption. It was hoped that such discoveries could help reduce the chronic surpluses that plagued agriculture.

The expertise of chemists, biochemists, chemical engineers, and microbiologists was soon put to work on weighty basic research projects. When, very early in its existence, the Center was approached to conduct work on mass-producing penicillin, a climate of cooperative discovery had already been fully established.

By 1945, American companies using these discoveries had achieved the astounding production of 14,000 pounds of penicillin—as compared to none in 1941.

The ability to produce useful drugs by fermentation revolutionized chemotherapy of microbial infections. Today these developments are still used in the production of many antibiotics.

*A wiped film molecular still apparatus distills high boiling fractions under vacuum.*

## Scientists Mass Produce Lifesaving Drug

Essential discoveries made at the Peoria facility enabled mass production of the life-saving drug penicillin. Corn steep liquor, a cheap byproduct of the wet corn milling industry, proved an ideal component of the growth medium, along with lactose. A superior *Penicillium* strain produced higher yields in liquid medium. And a submerged agitated fermentation system developed at the Center soon began bringing forth commercial quantities of penicillin.

Penicillin was only the beginning. A host of further accomplishments would soon add to the health, comfort, and wellbeing of Americans coast to coast.

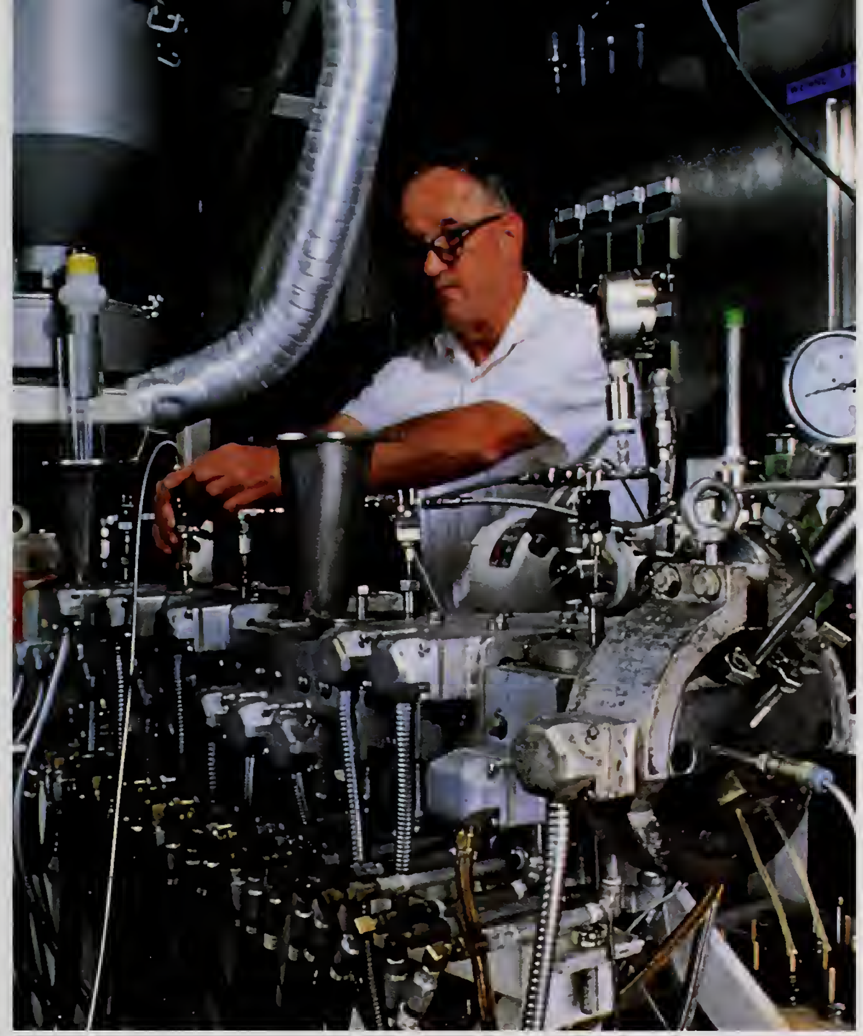
Some efforts have turned out to be continuous, such as the search for new products from uncultivated plants. This research resulted in the discovery of many new lipid structures and has given us crambe and jojoba as industrial oilseed crops and kenaf as a new fiber crop for papermaking. Several promising new industrial oilseed crops include lesquerella, cuphea, meadowfoam, and vernonia, also under scrutiny at NCAUR.

Polysaccharides produced by bacteria, for many years the target of investigation, continue to reveal their chemical nature and suggest uses. Two commercialized products developed by the Center are the blood extender dextran and xanthan gum, widely used as a thickening agent in foods and as a petroleum recovery agent.

Scientists developed a simple treatment for agricultural waste material, such as wheat straw and oat hulls. The process results in a product known as fluffy cellulose, which can be substituted for some of the flour in baked goods. Oatrim, another recent development that is now being commercialized, is a low-calorie fat substitute. Oatrim-containing products (ground beef, baked goods, dairy desserts) have more fiber as well as fewer calories and may also have cholesterol-lowering benefits.

The primary function of the ARS Culture Collection is to find and maintain useful or potentially

*Oatrim-containing products have more fiber as well as fewer calories and may also have cholesterol-lowering benefits.*



*Starch is converted to biodegradable plastic in a twin-screw extruder.*

useful microbial genetic material. One of only two large, publicly accessible culture collections in the United States, the collection numbers over 80,000 pure cultures of bacteria, yeasts, and molds. This repository is central to the burgeoning biotechnology industry, since in addition to natural strains, it maintains genetically engineered microorganisms that must be deposited in connection with biotechnology patents.

Starch as a major component of corn and wheat has been studied both from the standpoint of its basic chemistry and for new uses. One industrial development was Super Slurper, a water-collecting starch graft copolymer. Wherever the absorption of water is required, as in baby diapers, this material can be used.

Another recent development is the use of starch-based biodegradable plastic films to reduce pollution caused by nonbiodegradable plastics. Extrusion is a major commercial processing technology, and NCAUR is equipped with the latest twin-screw equipment. This is proving its value in the continuous, low-cost production of a variety of starch-based products. Of special interest is the application of the technology to continuous, large-scale encapsulation of pesticides in a starch matrix so they'll be released slowly, thereby reducing risk of pollution from excess.

NCAUR research has also produced a fungal amylase process for making alcohol fuel from cereal grains.

Foods based on soy protein led to development of several products. CSM (corn-soy-milk) and similar high-protein blends have found extended use overseas. High-quality food protein from soybeans and high-protein corn flour were both developed at NCAUR.

Sustained research has improved soybean oil in terms of flavor stability; and the chemistry of vegetable oils and fatty acids has been extensively investigated. This research helped establish soybean oil as the primary edible oil in the United States. Upping the nutritional quality of hydrogenated soybean oil and the physiological properties of soybean trypsin inhibitors are the subjects of intensive research. Scientists also developed polyamide resins from soybean oil and the use of linseed

## NCAUR Stirs Oriental Food Supply

NCAUR scientists have significantly contributed to the commercial availability of two oriental soybean foods now popular in the United States: tofu, a versatile semi-solid soy protein product made from soy milk, and tempeh, a simple fermented product made from whole soybeans. Other traditional oriental foods such as miso have been studied and their processing improved.

*Printing inks can now be made from soybean oil.*

oil curing for protecting concrete from weathering, important contributions to industry.

Fermentation research resulted in development of processes to produce vitamins $B_2$ and $B_{12}$ and beta carotene, and the important growth promoter, gibberellin. A glucoamylase for converting starch to useful sugar was central for development of high fructose corn syrup production.

Much research has been devoted to protecting our food and feed supply from mold toxins. Work began in 1963 on the cancer-inducing aflatoxins produced by *Aspergillus flavus.* Very sensitive, rapid mycotoxin screening assays were discovered and are today used worldwide. At the same time a cheap and effective method for decontamination of corn was developed based on the use of ammonia.

The impact of basic research should not be underestimated. For example, NCAUR scientists characterized the structure of phosphomannan fragments. These are now used to characterize and isolate mammalian phosphomannosyl receptors, and the peripheral lymphocyte homing receptor as well as to study lysosomal enzyme targeting. Today, virtually all literature in these fields refer to material provided by NCAUR. There have been vast studies of the immunochemistry of NCAUR dextrans. These studies have contributed significantly to an understanding of the specifications of carbohydrate reactions with antibodies and with animal and plant lectins.

A further example of basic research was the discovery of Brassinolide, a new plant-growth-promoting steroid from the pollen of *Brassica napus,* which is now being evaluated in many other laboratories.

# NCAUR Research: Spanning Major Arenas in Science

*Potentially beneficial toxins are extracted from fungi.*

## Bioscience

As the world looks for new ways to reduce dependence on finite resources, NCAUR methods that substitute plants and botanical resources for petroleum and coal have increasingly reached the forefront. In the past, NCAUR has been involved in alcohol fuels research and development. Significant progress was made in developing more effective fermentation and distillation processes and an improved feedstock in the late 70's and early 80's. Now with increased attention to clean air and oxygenates, a revived alcohol fuels and co-products program is underway. Three of the most promising research areas for more economical production of ethanol from renewable agricultural sources include: (1) less expensive substrates, (2) enzyme technology, and (3) development of superior ethanolgenic yeasts and bacteria through genetic engineering and biotechnological research. In addition, the prospect of genetically engineering plants as renewable sources of energy and chemicals offers vast promise in the face of declining supplies of resources.

### Tissue Culture

Plant tissue culture allows scientists to investigate plant metabolism, development, and growth without the difficulties of whole plants. Generally, tissue culture is either the random growth of cells or the specific manipulation

*Assessing the impact of river microorganisms on biodegradable plastic.*

of special cells to regenerate plants. But at NCAUR, tissue culture is also used to investigate secondary plant products and cell metabolism.

For example, when cells derived from developing corn seeds are grown in defined growth medium, many of the proteins that normally remain within the seed's cells are secreted. This process of protein secretion by cultured plant cells may ultimately produce biopharmaceuticals and other industrially important proteins.

## Corn and Soybeans Show Their Starch—and Sugar

Through elimination of undesirable components and modification of seed storage products, NCAUR researchers aim to improve the quality of corn and soybean seeds.

For example, corn kernels make only about 30 percent of their starch in the highly desirable straight-chain form called amylose. The rest of the starch is composed of highly branched molecules called amylopectin. Researchers are working to increase the percentage of the higher valued starch form in corn kernels.

Soybeans produce a class of indigestible sugars known as raffinose saccharides that contribute to the poor feed efficiency of soy meals. At NCAUR, investigations focus on the biochemical mechanisms responsible for production of these sugars in the developing soybean seed. This knowledge will be used to alter the genes of the soybean plant to reduce or eliminate accumulation of these indigestible sugars and enhance the value of soybeans in the marketplace.

## Biochemical Personalities

Microorganisms—life forms such as bacteria, molds, and yeasts—carry out several chemical reactions to sustain life and growth. Each reaction is performed by a protein called an enzyme. While all microorganisms share many similar biochemical reactions, microorganisms may also differ greatly from one another, as reflected by the specific enzymes they possess. Therefore, microorganisms can have a variety of biochemical personalities or abilities.

Differences between microorganisms arise because of differences in genes that code for specific protein or enzyme production. Scientists at

*Near infrared reflectance spectrometry enables scientists to measure oil and protein content in soybeans.*

*Wouldn't it be great if agricultural residues such as straws from oats, wheat, or rice, corncobs, and wood pulps . . . could be biologically converted into something commercially useful?*

*Supercritical fluid extraction of lipid-containing materials.*

NCAUR work with microorganisms with unusual biochemical abilities or use strains that have been genetically altered. These microorganisms may

- lead to new ways to use raw agricultural materials (corn starch, forages, soybean oil)
- create commercially useful products from agricultural wastes (hulls, fibers, distiller grains)
- produce materials containing microorganisms or microbial compounds for control of weeds or of plant diseases.

The ability to modify microorganisms by adding genes or extracellular DNA is an important advance that provides avenues for understanding and changing the biochemistry of a microorganism that can lead to development of commercially useful strains.

## Enzyme Solutions

Wouldn't it be great if agricultural residues such as straws from oats, wheat, or rice, corncobs, and wood pulps, as well as prairie or other grasses, could be biologically converted into something commercially useful? Unfortunately, all these starting materials contain large amounts of tough plant fibers known as cellulose and xylan.

Several research groups at NCAUR are taking a creative look at biologically generated enzymes that can degrade these fibers. It was found that a highly pigmented fungus, *Aureobasidium*, produces a very active form of the xylanase enzyme that offers great potential in treating wood pulps to produce fibers for high quality papers and in processing of foods such as fruit juices. It might also help cows digest feed materials they otherwise could not, leading to lower production costs of milk and meat.

A unique enzyme was found in the yeast *Candida* that can degrade cellodextrin polysaccharides derived from cellulose into sugars. If the gene for this enzyme can be isolated, it may be inserted into alcohol-producing yeast strains. Possible result: agricultural residues that can be converted into ethanol for use in motor fuels.

# Food and Fiber Science

How foods are processed and how they are made available has enormous dollar-influence in today's marketplace. Researchers at NCAUR are looking at starches and proteins—components of foods and industrial products—in terms of not only molecular composition but also the mechanical and thermal forces that shape their processing. These are complex scientific problems, like understanding the response of these materials to flow and deformational (rheological) forces. For example, what difference does wheat variety make when it comes to processing of wheat flour doughs?

*A researcher evaluates damaged soybeans and compares them to sound soybeans.*

Another problem area relates to the processing of starches, which can be dispersed in water in a variety of ways, including pasting at temperatures below 100°C and jet cooking under extreme conditions of flow, temperature, and pressure. Different treatments result in different properties—for reasons which are complex and only partly understood. Such fundamental scientific and engineering research provides quality control data that can pay off on the supermarket shelf and enhanced American market share.

## The Food in Our Future

Wheat—in each of its several types which include hard wheat (which makes bread), soft wheat (for cakes, crackers, and cookies), and durum wheat (for spaghetti and macaroni)—is a staple of the American diet. Wheat's elastic gluten proteins play a critical role in bringing wheat products to the table. NCAUR scientists work to uncover how gluten influences wheat quality and provide information that helps breeders develop new, improved varieties.

As popular as high fiber diets have recently become, there may be a nutritional cost. Some dietary fiber sources have the ability to bind nutritionally important minerals such as calcium, zinc, and iron. Scientists at NCAUR have measured the mineral absorption capacity of different kinds of fibers—wheat bran, oat hull, corn bran, and soybean hull. Using an x-ray microscope and computer modeling, researchers are establishing valid guidelines for meeting

*A taste panel determines the frying qualities in cooking oils.*

*Analysis of deteriorated soybean oils by gas chromatography-mass spectrometry.*

*Designer oils will be a common part of our future diet just as designer jeans are found in the wardrobe.*

dietary mineral requirements in high-fiber diets.

Fats, lipids, triglycerides, hydrocarbons—molecules that contain large proportions of carbon and hydrogen—add texture and palatability to our foods, value to household goods, and performance to our cleaning agents and our machinery. But the fat should fit the task. For example, for dietary purposes unsaturated fats are good and saturated fats are not so good. But in automotive crankcase oil and transmission fluids, the opposite is true.

Designer oils will be a common part of our future diet just as designer jeans are found in the wardrobe. Scientists now have the capability to modify soybean and other oil-producing plants to design "new" oils with better nutritional properties or that produce better tasting foods.

High-tech human metabolic studies at NCAUR use nontoxic, nonradioactive deuterium isotopes (heavy hydrogen) to trace the course of isomeric fatty acids in human subjects rather than in animal models. It was previously impossible to obtain this type of data from normal healthy human subjects.

And that's not all. Armed with computer modeling software and knowledge of properties that are needed, the chemist can build molecules atom by atom, change molecular shapes, move molecules, and determine if their shapes and packing will provide the properties needed in a particular task. New and unusual structures can be examined easier and in greater detail by computer than by other methods.

# Industrial Products Science

## Starch-Based Plastics

Starch, a type of natural polymer produced by many plants, may be combined with synthetic petroleum-derived polymers or with thermoplastic natural polymers to produce plastic materials with altogether different properties.

Starch-based plastic materials may degrade more rapidly and more extensively, if carelessly discarded as litter, than pure synthetic materials. Cornstarch-based plastics that biodegrade would be of benefit to agriculture too. Faster or total decomposition of litter would reduce danger of wildlife entrapment and lessen clutter in the landscape.

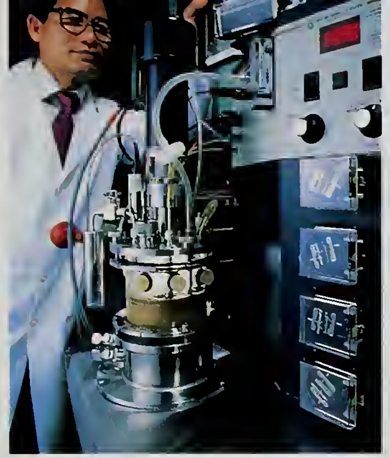
*Measuring the tensile strength of starch-based plastics.*



NCAUR researchers are working on new starch-based chemicals for urethane foams, starch graft copolymers for water-absorbent materials, starch-encapsulated herbicides for weed control, and starch-plastic premixes for blown film.

## Enzymes as Industrial Agents

Certain enzymes, obtained from plants or microorganisms, can rearrange the components of vegetable oils to give new physical properties and thus provide for expanded uses of these oils. Other enzymes have been found that break vegetable oils down into fatty (long carbon chain) acids and glycerol, a 3-carbon alcohol. These oil-derived substances may be further modified by different enzymes to produce new products that have industrial application.



*A mini-fermentor converts soybean oil into value-added industrial products.*

Examples of these applications include such products as cosmetics, lubricants, coatings, detergents, and chemicals for manufacturing other useful products.

## Automotive Vegetable Oils

Vegetable oils already perform well in diesel engines in short-term testing. However, extended use of these oils presents serious problems due to incomplete combustion—caused, in part, by the high viscosity (thickness) and high boiling point of vegetable oils. NCAUR scientists are conducting fundamental studies that will give a better understanding of combustion chemistry. With this information, new technologies can be designed that will improve the combustion process.

## And More

New products from new industrial oilseed crops are continually brought forth. New high-temperature lubricant additives are being developed from the unique long-chain fatty acids of meadowfoam oil, and grease thickeners from the hydroxy acids of lesquerella are progressing. Scientists at NCAUR are not only finding processing methods for unique new crops, they're also discovering applications from these materials.

High-pressure technology is solving a variety of problems important in the processing and use of agricultural materials. Research is directed to the exploitation of the unexpected solvent power of carbon dioxide under high-pressure conditions where the $CO_2$ becomes a supercritical fluid. For example, supercritical fluids can extract oils from oilseeds of many types—affording safe alternatives to hazardous, flammable, and explosive petroleum solvents used commercially.

*Insects produce phero-mones, natural chemicals that enable them to communi-cate.*

# Crop Protection Science

## Chemicals That Release Slowly

One way to make chemical pesticides stay put and perform their function well is to encapsulate them in a starch matrix. Encapsulation greatly reduces losses of pesticide due to volatility, leaching by water, and decomposition by light. Since the pesticide stays where targeted, it is used more efficiently, reducing risk to the environment.

At NCAUR, starch-encapsulated herbicides are evaluated against commercial formulations in large-scale field studies that compare weed control methods in terms of groundwater contamination.

## What Else Can Be Encapsulated?

A patented process using starch for encapsulation is effective also in protecting flavors, drugs, and nutrients for use in foods and feeds.

Bacteria and viruses that kill pest insects are also ideal candidates for the starch encapsulation process.

## Insect Pheromones

Insects produce pheromones, natural chemicals that enable them to communicate—for example, to attract mates or signal each other of a threat. These chemicals are exceptionally active—a few billionths of a gram of the proper compound is often sufficient to

attract an insect. Each species of insect can be expected to have its own unique pheromone.

Pheromones have great potential for environmentally safe pest control. They are extremely active even in tiny amounts, are very specific for a certain kind of insect, and have very low toxicity.

One tactic is to permeate the air with pheromone, thereby confusing the pest insects and preventing them from finding the opposite sex and reproducing. Another approach is to combine the pheromone with a small amount of insecticide, allowing the pest species to be controlled with far less insecticide than usual and with less harm to other organisms. At NCAUR, scientists study the chemical structures of pheromones of insects that occur worldwide so it

*A sap beetle responds to its pheromone in a wind tunnel. Beetles alight on filter paper treated with the sex attractant.*

would be expedient to synthesize large amounts of the compounds.

## Fungal Pathogens

NCAUR scientists develop methods for controlling noxious weeds and insects by infecting them with naturally occurring fungal pathogens. Using fungal plant pathogens as bioherbicides and bioinsecticides has many advantages including effectiveness against weeds and insects that are difficult to control with chemical herbicides, little or no damage to nontarget plants, and little environmental impact.

## Natural Plant Chemicals

The isolation, purification, and identification of natural plant growth regulators and the evaluation of these compounds for commercial use may lead to a better understanding of how plants compete for light, water, and nutrients.

Less well established is the natural chemical competition that they undergo; this competition is known as allelopathy. Many plants release compounds into the environment that are toxic to neighboring plants (even those of their own species). These compounds may be transported by water through the soil or, if they are volatile, by the wind.

While basic research into plant-plant chemical competition provides insight into the complexity of nature, the ultimate goal of NCAUR research is to provide new herbicides that pose less harm to the environment than some currently in use.

## Science of Natural Toxins

Poisonous chemical compounds called mycotoxins occur on grains and other foods and feeds because of fungal growth. When they are ingested by humans and animals, disease may result. Certain mycotoxin-induced diseases can lead to sudden death. Others may be more prolonged, resulting in poor weight gains, suppression of immunity, or tumors.

NCAUR researchers are working to control or prevent such contamination, starting with fast and accurate ways to detect and quantify mold populations. Suspected toxin-producing molds are isolated into individual culture tubes are tested for their ability to produce specific mycotoxins. When a feed is toxic to livestock or poultry, but no known mycotoxins can be detected in

*DNA screening of gene required for biosynthesis of mycotoxins.*

samples of that feed, a search begins for a new mycotoxin—a search that can be difficult because the chemical structures of mycotoxins are diverse. Toxic effects of some of these toxins are studied in tissue culture rather than in laboratory animals.

One of the most worrisome mycotoxin-producing fungi is *Aspergillus flavus*. This fungus, which generates aflatoxin, is particularly difficult to control; it not only spreads from cornstalk to cornstalk via windborne and insect-carried spores, but also sustains life for many years in survival structures called sclerotia. Both types of propagules are associated with damaged corn kernels and are dispersed onto the ground during combine harvesting. There's been substantial progress made in understanding the disease cycle of this fungus in nature and now scientists are studying different approaches to control and reduce the fungus in cornfields.

Developing methods to control mycotoxins requires basic knowledge of the way in which they are produced; often, toxin formation is the result of a long and complex process. Creative research tactics are often required. For example, NCAUR scientists determine many of the steps leading to the formation of *Fusarium* mycotoxins by studying fungi that have been genetically altered so that they no longer make mycotoxins. These genetically altered fungi are also used to demonstrate that the production of mycotoxins plays a role in plant diseases caused by *Fusarium*.

*NCAUR is in a unique position to contribute to the agricultural goals of tomorrow.*

*Cold storage of microorganisms in the culture collection.*

# NCAUR into the 21st Century

Thanks to its existing scientific expertise and research capability, NCAUR is in a unique position to contribute to the agricultural goals of tomorrow. This means:

- development of new products and uses from surplus agricultural commodities
- technology to produce agriculturally derived fuels and other byproducts having high industrial value
- new approaches to minimize or eliminate toxic metabolites from food and feedstuffs
- new approaches to stimulate and accelerate technology

*Analysis of DNA by agrogel electrophoresis visualized by ultraviolet radiation.*

*Technology transfer will receive a boost when, in 1995, NCAUR's modern pilot plant is completed.*

transfer between NCAUR and the private sector that take full advantage of the authorities provided in the Technology Transfer Act of 1986 (PL-99-502).

Technology transfer will receive a boost when, in 1995, NCAUR's modern pilot plant is completed. This planned facility will provide modular space for pilot scale-up, onsite private industry access to the NCAUR technology, and testing equipment. The private sector will provide capital funds, manufacturing and production equipment, and technical support so that ARS technology can be brought up to commercial scale.

This approach will facilitate the commercialization of NCAUR-developed technology; will minimize the financial burden to the Federal Government; will provide unique facility, equipment, and expertise to the private sector; and will eliminate the need for NCAUR to invest large sums of money into scale-up technology that is rapidly outdated.

Many of the major building systems—heating, ventilating, air conditioning, electrical, roofs, and infrastructure (paving, steam and waterlines, and waste treatment and disposal systems)—are to be totally renovated by 1997. Other safety and health needs, such as asbestos removal and building code upgrade requirements, will be included.

The NCAUR scientific staff looks forward to entering the 21st Century in an environment that properly enhances our state-of-the-art research.


*Photoacoustic methods are used to evaluate corn.*


SEARS

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# Peoria, the River City

With a metropolitan area population of 350,000, Peoria is considered one of the most desirable communities in the Midwest. It is the strategic center for communications to other important cities; Chicago is 150 miles away; St. Louis, Missouri, is 165. The Illinois River, which forms the eastern boundary of Peoria, is a vital transportation artery.

The River City affords surprising cultural amenities, including a symphony orchestra, civic chorale, ballet, and opera. A fine educational complex includes 153 public and private elementary schools, 33 secondary schools, and 5 major institutions of higher learning.

*Skyline at night.*

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